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Original Article

DEFECT ANALYSIS OF INLET TUBE CASTING BY COMPUTER SIMULATION

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ABSTRACT

The main defects in casting categories are solidification related defects (shrinkage, porosity defects, hot tears, cold shut, metal penetrations etc). In the modern developing industries, casting foundries suffer from poor quality and productivity. Casting defects can be reduced or controlled by controlling and optimizing manufacturing process parameters for zero defects. As a part to reduce the defects, design engineers have to use large safety factors. In many designs, due to lack of knowledge for the casting, process is playing a major role. Casting Simulation Technique now have become a powerful tool for understanding the Casting process, Mold Filling, Solidifaction and Location of Internal Defects. This case describes the advantage & benefit of Casting Simulation, and, by which method defects can be reduced with theoretical background as well as simulation process.

KEYWORDS: Introduction to Casting, Casting Defects, Computer Simulation Process & Comparison

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INTRODUCTION

Today, the best and economical manufacturing process is Casting Process. This process is very complicated as it covers more and more theoretical background like solidification, strength, hardness etc. In casting process, the location size & shape of Riser depend on the design & geometry of the casting and also Mold Design and other process parameters. For proper results, the experimental routs are good for design and development of mold design for optimum process parameters. However, in most of the cases, it is impossible as the process consumes time. There fore, casting simulation process is a very good way of proper design of casting components with various suitable parameters. Now a days, Casting Simulation Softwares are developed, and it is used for casting defects and problem. Use of this software minimizes the shop floor trial & achieves the best quality within the highest possible time. The detailed path for the Simulation Process is described in the figure -1.

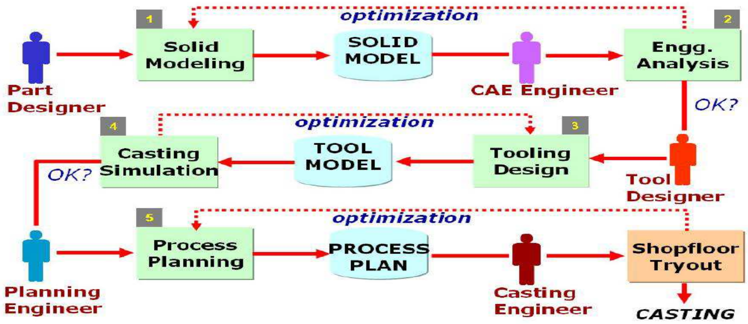


Figure 1: Optimization in Foundry at Various Stages [10]

DIFFERENT TYPES OF DEFECTS OCCURRED DURING CASTING

The different types of defects that occur during casting are given in figure – 2. The are,

- Shrinkage
- Porosity
- Hotspot
- Hot tear
- Blowhole
- Shift
- Cold Shut and Mis-Run

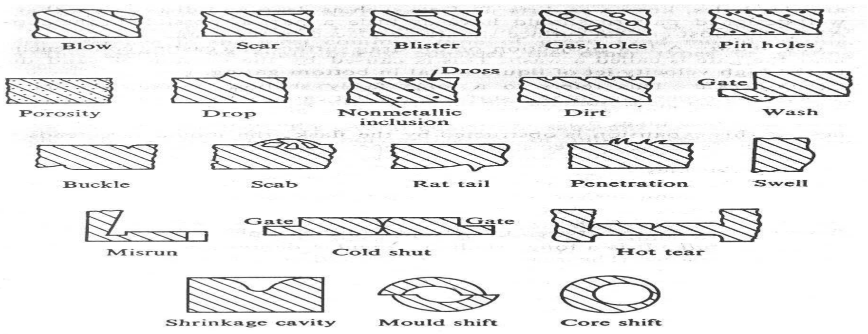


Figure 2: Common Casting Defects

EXISTING PROBLEMS IN INLET TUBE

The defects like residual stresses, temperature, fast cooling rate, improper design of gating system are because of improper solidification of the Inlet tube. These defects are shown in figure -3.

Figure 3: Existing Product with Defect

CASTING SIMULATION

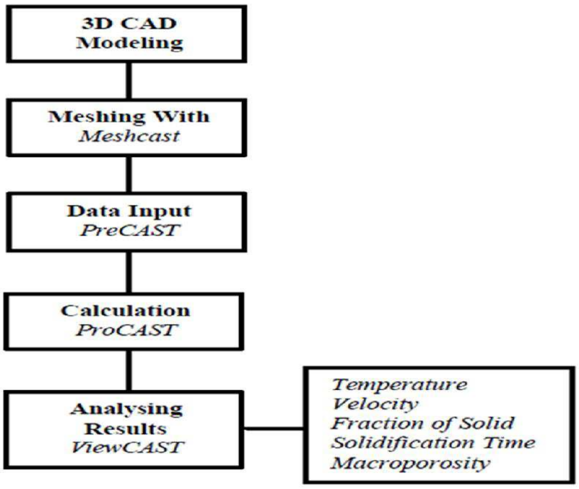


Figure 4: Steps That are Required for Simulation

MODELLING STEPS AND SIMULATION

When a parent feature is modified, its child features are automatically modified. It is therefore essential to reference the feature dimensions. Hence, the design modifications are correctly propagated through a model.

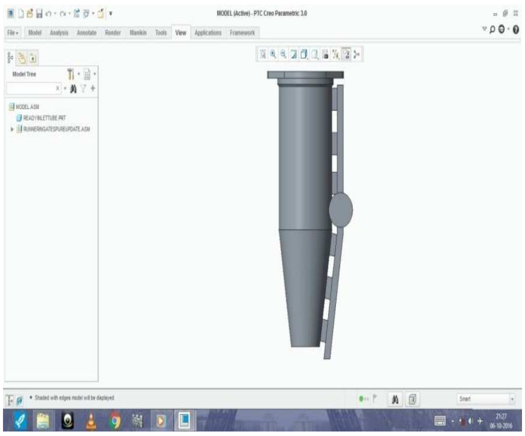


Figure 5: 3-D Model

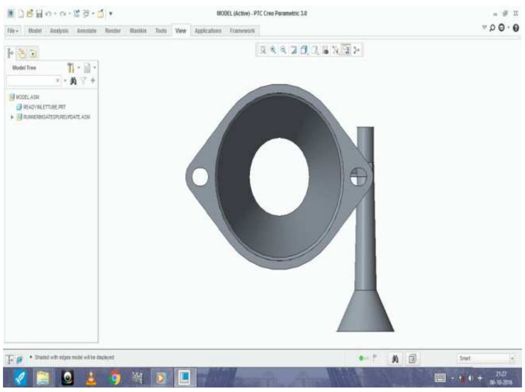


Figure 6 Top View of Inlet Tub

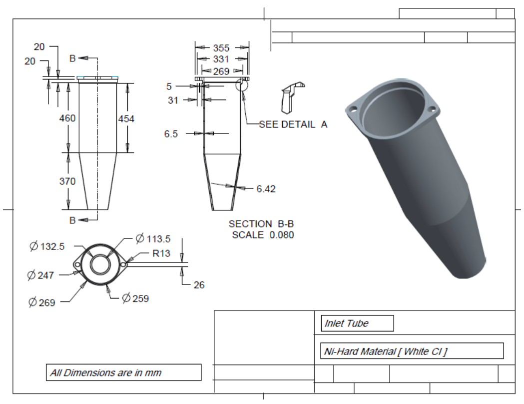


Figure 7: Dimension of Inlet Tube

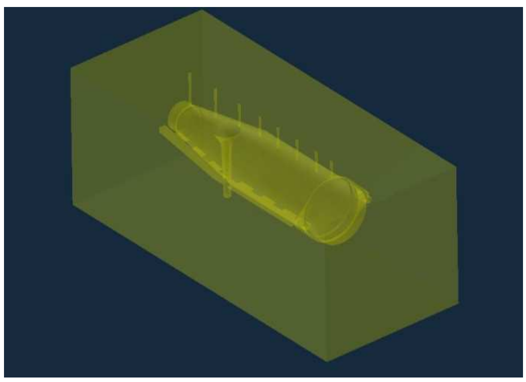


Figure 8: Inlet Tube with Mould Box

GENERAL WORKFLOW

There are six major steps in Mesh CAST, that are required in order to produce a high quality tetrahedral mesh. The work steps that are followed, when using Mesh CAST depends upon the following: the nature of the project, the intended use of the meshes generated by Mesh CAST and the type and quality of CAD model used as the initial input.

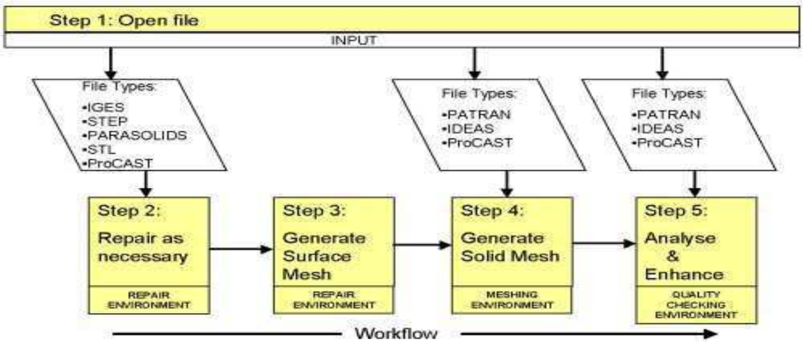


Figure 9: Diagram of Meshcast

It is important to note that, working with MeshCAST always begins by opening a file. After the file has been loaded, one can begin working on the corresponding work step in the process. From this entry point to the final generation of the Tet mesh, the steps one follows and the MeshCAST tools used will be the same, regardless of the type of input file used.

CALCULATION OF INLET TUBE WITH NRL (NAVAL RESEARCH LABORATORY) METHOD

- **Pouring Time**

Pouring Time t = K (1.41+ (T/14.59)) (W) ^ (1/2)

= 2.08 (1.41+ (12/14.59) (44.5) ^ (1/2)

= 2.08 (1.41+0.825) * (6.65)

t = 30.91 Sec

Where, K= (fluidity of iron in inches / 40)

K= 2.08 (for thinner sections)

K= 2.67 (for sections 10 to 25 mm thick)

K= 2.08 (for heavier sections)

T = average section thickness, mm

W = mass of casting, kg

- **Choke Area**

The choke area can be calculated using Bernoulli's equation as

A = ((W) / (d*t*C (2gH) ^ (1/2)))

Where, A = choke area, mm2

W = casting mass, kg

t = pouring mass, s

d = mass density of the molten metal, kg/mm2

g = acceleration due to gravity, mm/s2

H = effective metal head (sprue height), mm

C = efficiency factor which is a function of the gating system used

Volume of the casting = 1290*380*245

= 120*10^6 mm3

Weight of the casting = 44.5 kg

A = ((44.5) / ((7.86*10^ -6)*30*0.85)*(2*9800*185)^(1/2)

A = 116.5 mm2

Diameter Of choke, D = 11 mm

- **Ingate Design**

Flow rate, Q = (45/30.91) = 1.44 kg/s

Q = ((1.44*1000)/ (6.9*10^-3)) = 208.7*10^3 mm3/sec

Velocity of metal, V = ((208.7*10^3)/598.5) = 348.7 mm/sec

h = 1.6(((Q^2)/(g*b^2)))^(1/3) + (V^2 / 2g)

= 1.6 (((208.7*10^3)^2 / (9800*40*40))^(1/3) + (((348.7)^2 / (2*9800))

= 1.6*14.057+6.2

= 28.7 mm

Hence, gate height H = h – 5

= 28.7 -5

= 23.7mm

Note: Gates higher than this will not fill completely and those lower than this will increase the velocities of the stream entering into it.

Table 1: Input Data

1	Pouring Temperature	1480 c
2	Composition of Casting	Ni-Hard 3% C, 9% Cr,5% Ni, 2% Si
4	Casting Volume	120000000 mm3
6	Mould Box Size	1420*510*410 mm
7	Weight of Casting	54 Kg
8	Core Material	Silica Sand+Mollasis
9	Sand Type	Silica Sand

10	Inspection Test Type	Visual & Radiology
11	Pouring Time	34 Sec
12	Ingate Size	50*50*5 mm
13	Feed Aids	Exothermic Sleeve, Chills
14	Density	7.78 gm/cm2

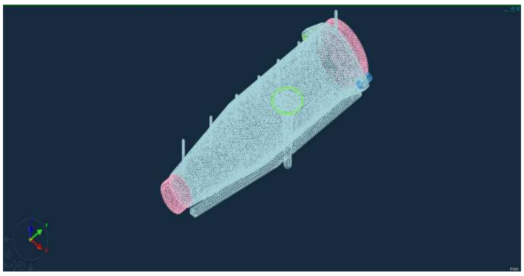


Figure 10: Meshed Model

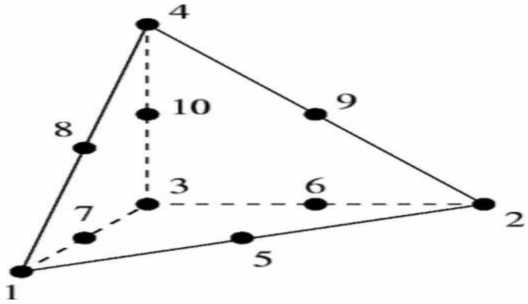


Figure 11: Tetrahedral Element

Table 2

Type of Mesh: - 3D	**Type of Element: - Tetrahedral**
Type of Element: - Tetrahedral	**Number of Nodes: - 450332**
Number of Elements: - 243274	

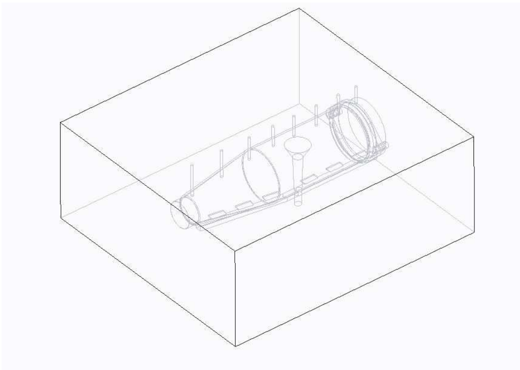


Figure 12: Mould Box with Object

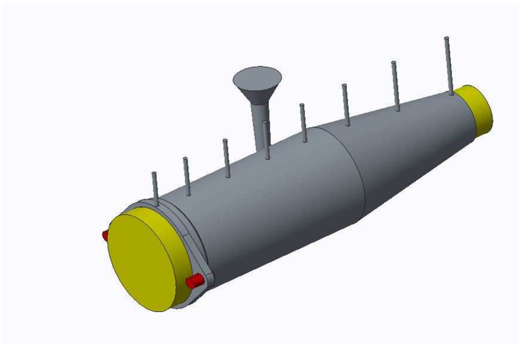


Figure 13: Model with Cores

Table 3: Material Composition of Ni-Hard

Material	Carbon C %	Chromium Cr%	Nickel Ni%	Silicon Si %
Ni-Hard	3	9	5	2

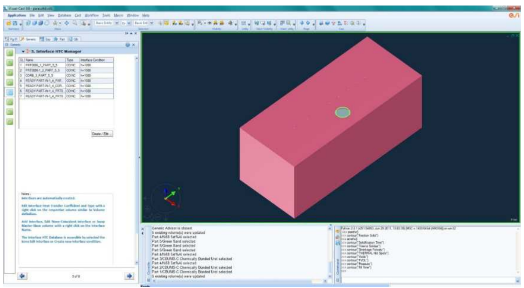


Figure 14: Mould

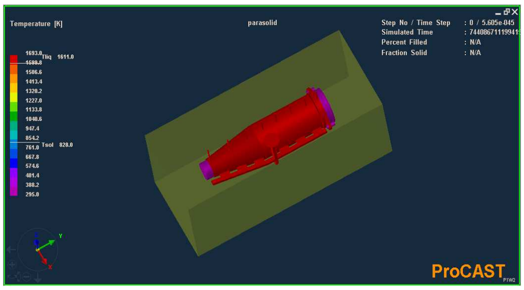


Figure 15 Temperature Contour

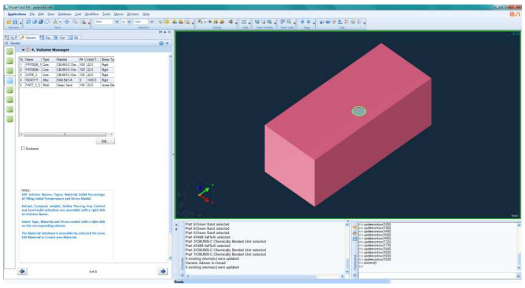


Figure 16: Applying Material Properties

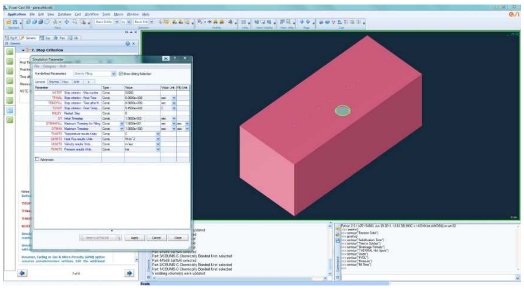
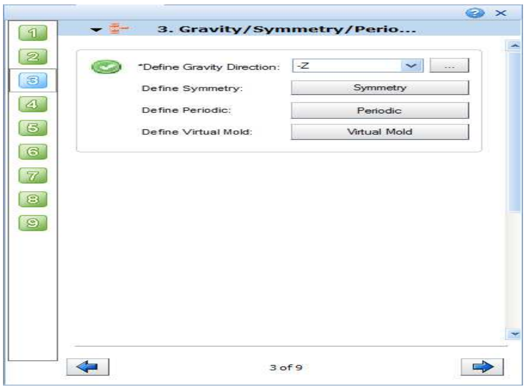
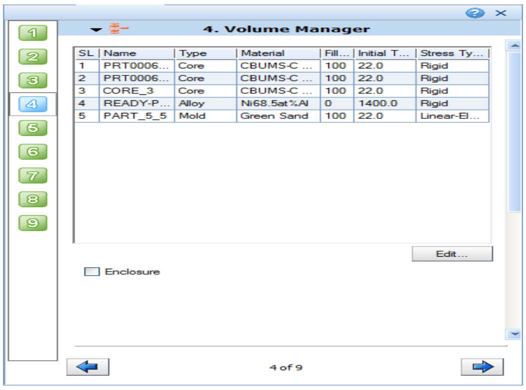


Figure 17: Run Parameters

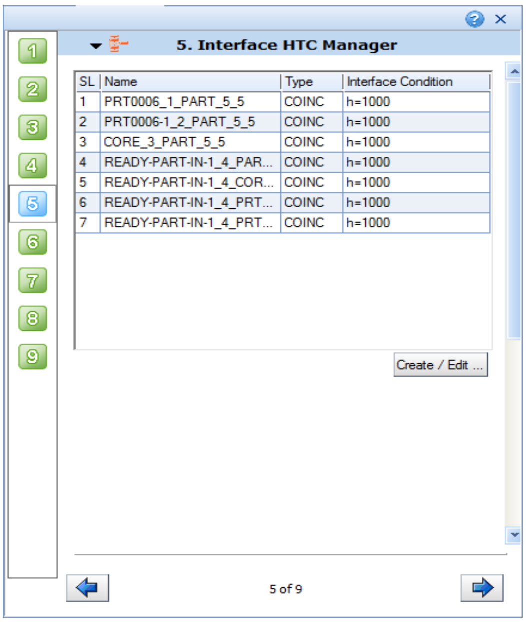
In precast step, run parameter in general menu given in this, fill up the max step for running the software, final temp and time filling for casting material.



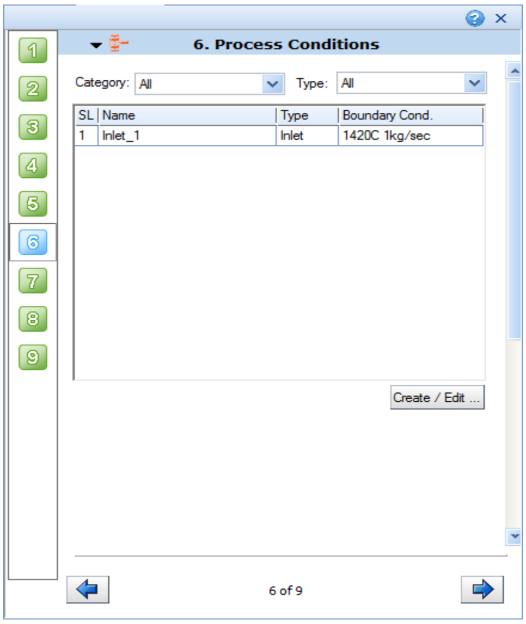
Steps 3: Applying Gravity Direction



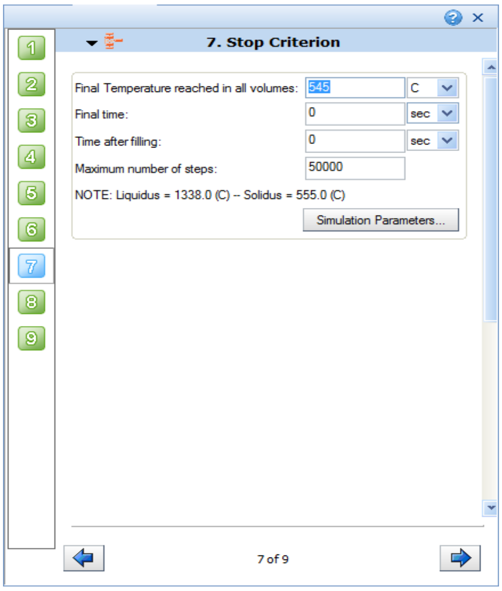
Steps 4: Volume Manager

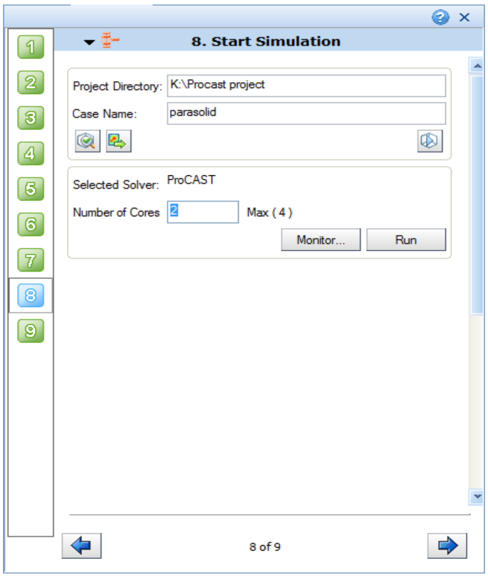


Steps 5: Interface HTC Manager



Steps 6: Process Conditions





Steps 7: Stop Criterion **Steps 8: Start Simulation**

STAGE 1: INITIAL RESULTS

Numerical Calculation

- **Old Data**

Calculation of Housing with NRL (Naval Research Laboratory) Method.

- **Pouring Time**

Pouring Time t = K (1.41+ (T/14.59)) (W) ^ (1/2)

= 2.08 (1.41+ (12/14.59) (44.5) ^ (1/2)

= 2.08 (1.41+0.825) * (6.65)

t= 30.91 Sec

Where, K= (fluidity of iron in inches / 40)

K= 2.08 (for thinner sections)

K= 2.67 (for sections 10 to 25 mm thick)

K= 2.08 (for heavier sections)

T = average section thickness, mm

W = mass of casting, kg

- **Choke Area**

The choke area can be calculated using Bernoulli's equation as

A = ((W) / (d*t*C (2gH) ^ (1/2)))

Where, A = choke area, mm2

W = casting mass, kg

t = pouring mass, s

d = mass density of the molten metal, kg/mm2

g = acceleration due to gravity, mm/s2

H = effective metal head (sprue height), mm

C = efficiency factor which is a function of the gating system used

Volume of the casting = 1290*380*245

= 120*10^6 mm3

Weight of the casting = 44.5 kg

A = ((44.5) / ((7.86*10^ -6)*30*0.85)*(2*9800*185)^(1/2)

A = 116.5 mm2

Diameter Of choke, D = 11 mm

- **Ingate Design**

Flow rate, Q = (45/30.91) = 1.44 kg/s

Q = ((1.44*1000)/ (6.9*10^-3)) = 208.7*10^3 mm3/sec

Velocity of metal, V = ((208.7*10^3)/598.5) = 348.7 mm/sec

h= 1.6(((Q^2)/(g*b^2)))^(1/3) + (V^2 / 2g)

= 1.6 (((208.7*10^3)^2 / (9800*40*40))^(1/3) + (((348.7)^2 / (2*9800))

= 1.6*14.057+6.2

= 28.7 mm

Hence, gate height H = h – 5

= 28.7 -5

= 23.7mm

Note: Gates, higher than this will not fill completely and those lower than this will increase the velocities of the stream entering into it.

RESULT 1-: INITIAL SOFTWARE RESULTS

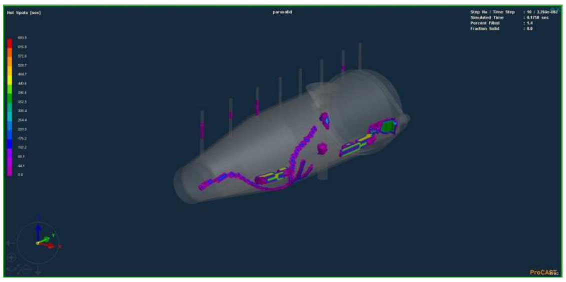


Figure 18: Hot Spot Defect

Above figure shows the Hot Spot Defect in actual parts

Table 4: Optimization of Casting by Changing Risers Height& Runner Width

Sr No.	Riser Height (mm)	Runner Height (mm)	Runner Width (mm)
1	157	83	15
2	150	80	20
3	140	70	25
4	148	72	22
5	160	75	30
6	**157**	**83**	**20**

STAGE 2: OPTIMIZATION

Numerical Calculation

- **New Data**
  - Pouring Time

Pouring Time t = K (1.41+ (T/14.59)) (W) ^ (1/2)

= 2.08 (1.41+ (12/14.59) (54) ^ (1/2)

= 2.08 (1.41+0.825) * (7.34)

t = 34.12 Sec

Where, K= (fluidity of iron in inches / 40)

K= 2.08 (for thinner sections)

K= 2.67 (for sections 10 to 25 mm thick)

K= 2.08 (for heavier sections)

T = average section thickness, mm

W = mass of casting, kg

- **Choke Area**

The choke area can be calculated using Bernoulli’s equation as

A = ((W) / (d*t*C (2gH) ^ (1/2)))

Volume of the casting = 1320*510*410

$= 276*10^6\ mm^3$

Weight of the casting = 54 kg

$A = ((54) / ((7.86*10^{-6})*30*0.85)*(2*9800*185)^{(1/2)})$

$A = 124.5\ mm^2$

Diameter Of choke, D = 12.98 = 13 mm

- **Ingate Design**

Flow rate, Q = (54/34.91) = 1.56 kg/s

$Q = ((1.56*1000)/ (6.9*10^{-3})) = 0.2*10^6\ mm^3/sec$

Velocity of metal, $V = ((0.2*10^6)/2500) = 80$ mm/sec

$h = 1.6(((Q^2)/(g*b^2)))^{(1/3)} + (V^2 / 2g)$

$= 1.6 (((0.2*10^6)^2 / (9800*25*25))^{(1/3)} + (((80)^2 / (2*9800))$

$= 1.6*14.057+0.3265$

$= 30.23$ mm

Hence, gate height H = h – 5

= 30.23 - 5

= 25.23mm

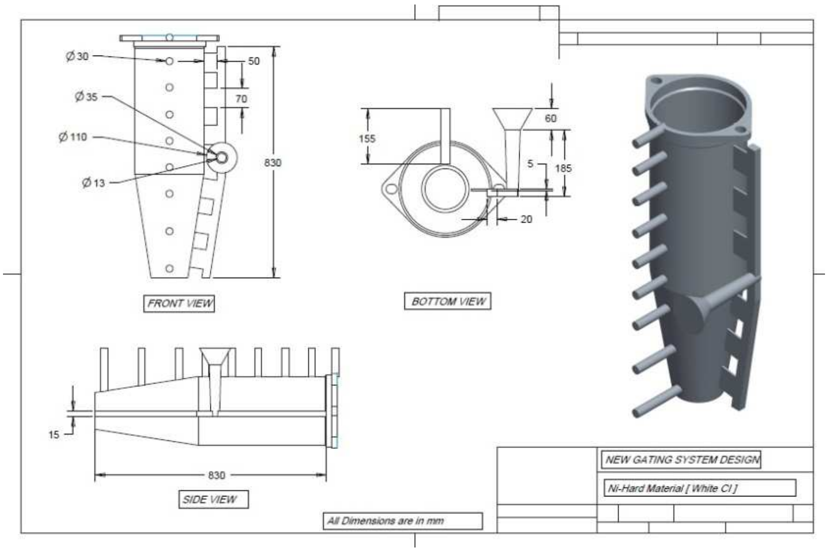


Figure 19: New Gating System Design

TEMPERATURE CONTOUR

Initially, When Metal is poured in the Mould

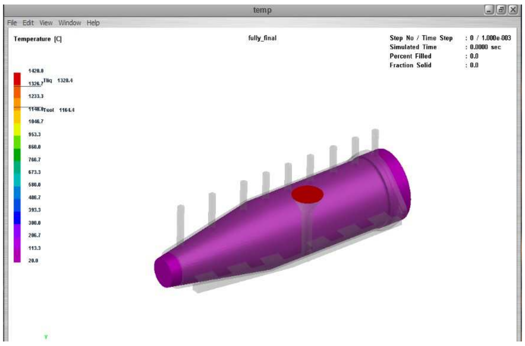


Figure 20: Step No. - 0

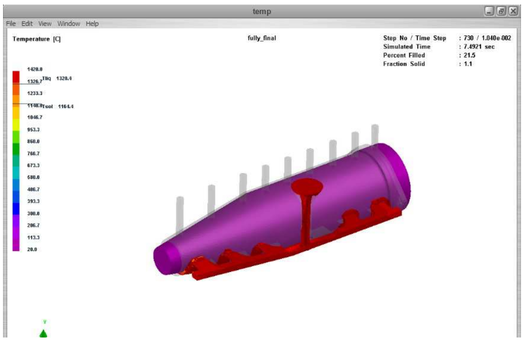


Figure 21: Step No. – 730

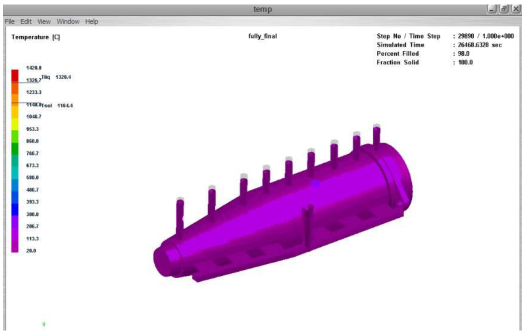


Figure 22 Step No. – 29890

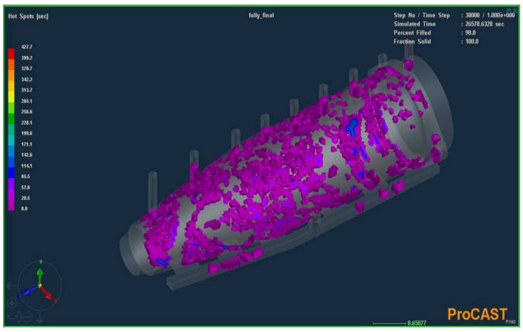


Figure 23 Optimized Software Results

STAGE 3: COMPARISON

New shape factor:-

- Casting dimensions = 1320 * 510 * 410
- Calculation = 1320 + 510 / 410 = 4.46
- Volume of the Casting = 276 * 10^{6}
- Volume of the Riser

Vr / Vc = 0.42

Vr = 1.2*4.46

= 4.992

Vr = (DH/2D+4H) (Assume H=D)

= (D^2 / 6D)

4.992 = D/6

D = 29 mm (Assume 25 mm)

Old Shape Factor

- Casting dimensions = 1290 * 380 * 245
- Calculation = 1290 + 380 / 245 = 6.81
- Volume of the Casting = 120 * 10^{6}
- Volume of the Riser

  Vr / Vc = 0.51

  Vr = 0.51 * 120 * 10^{6}

  = 61.2 * 10^{6} mm3

  D = 50 mm

Table 5: Difference between Calculations

	OLD CALCUTUTION (mm)	NEW CALCUTATION (mm)
POURING TIME	25 SEC	34 SEC
MOULD BOX SIZE	1290*380*245	1320*510*410
INGATE DESIGN	70*50*10	50*50*15
NO.OF RISER	8	9
RUNNER DIMENSION	860*29*21	830*20*15
CHOKE DIA.	11	13
RISER DIA.	15	30
POURING TEMP.	1400 ℃	1480 ℃
WEIGHT OF CASTING	44.5 KG	54 KG

CALCULATION OF CASTING YIELD

- Volume of Component = 4.3934 × 10^{6} mm3

  Surface area = 1.224 × 10^{6} mm2

  Mass of Casting = 4.3934 × 10^{6} TONN

- Volume of total Casting (Old gating system + Component)

  = 5.629 × 10^{6} mm3

  Surface area = 1.423 × 10^{6} mm2

  Mass = 5.629 × 10^{6} TONN

  Casting yield = (Volume of component / Total volume) × 100 % = 78.04%

- Volume of total casting (New gating system + Component)

  = 5.948 × 10^{6} mm3

  Surface area = 1.470 × 10^{6} mm2

  Mass = 5.948 × 10^{6} TONN

  Casting yield = (Volume of component / Total volume) × 100 %

= 73.86 %

ACKNOWLEDGEMENTS

The authors are grateful to Shree Vallabh Alloy Steel Casting for carrying out this project.

CONCLUSIONS & FUTURE SCOPE

From the present work, it can be concluded that optimization in current gating system design could be done to increase the casting yield. In casting simulation software (PROCAST), by comparing that result with calculated data for same component and after validation, we can reduce residual stresses, fast cooling rate, improper design of gating system of the inlet tube of the casting. An experimental method like trial and error method is very time consuming. It gives result, but take more time. This software is giving accurate result. The software gives solidification time, defect location and gives a solution for defect removal. Advanced casting simulation tools like PROCAST, SOFTCAST, AUTOCAST proves to be very effective in carrying out the analysis of various casting defects, by changing the design of gating system, riser, runner, spare, feeder etc and these effects can be eliminated.

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